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Citation for published version:
Webb, J 2015, 'Improvising Innovation in UK Urban District Heating: the Convergence of Social and Environmental Agendas in Aberdeen', *Energy Policy*, vol. 78, pp. 265-272.
https://doi.org/10.1016/j.enpol.2014.12.003

Digital Object Identifier (DOI):
10.1016/j.enpol.2014.12.003

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
Energy Policy

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OPEN ACCESS

Download date: 06. May. 2023

Elsevier Editorial System(tm) for Energy Policy
Manuscript Draft

Manuscript Number:

Title: 'If it hasn't been done in Aberdeen, it's not worth doing': Developing Urban Heat Networks in the UK.

Article Type: SI: Urban energy governance

Keywords: heating; energy governance; Aberdeen

Corresponding Author: Professor Janette Webb, PhD

Corresponding Author's Institution: University of Edinburgh

First Author: Janette Webb, PhD

Order of Authors: Janette Webb, PhD

Abstract: Research on urban heat networks, or district heating, as a contributor to UK policy goals for low carbon, secure and affordable energy has focused mainly on technical and economic factors, with limited analysis of social, and political dimensions. This paper examines these dimensions through a case study of the city of Aberdeen, north east Scotland. Interviews and documentary analysis are used to examine the formation of a non-profit energy business in 2002, and its subsequent growth. Results show that technical and economic assessments were insufficient in themselves to establish local investment. In the UK centralised energy generation and supply context, lack of local energy governance capacity and expertise were problematic. Council commitment to reduce fuel poverty, combined with increasing UK political orientation to climate change, created a willingness to experiment through improvised learning and financial bricolage. The social welfare priority resulted in decision to proceed via a non-profit locally-owned organisation, using cost- rather than market-based heat tariffs. AHP has developed three energy centres and heat networks, supplying 34MWhr of heat. Carbon savings are 45% in comparison with electric heating, and heating costs are reduced by the same amount. In conclusion, the paper outlines policy measures to accelerate governance innovation.

'If it hasn't been done in Aberdeen, it's not worth doing': Developing Urban Heat Networks in the UK.

Highlights:

- District heating is an effective carbon saving measure for UK cities
- Lack of capacity and expertise pose development difficulties for local authorities
- In Aberdeen improvised learning and financial bricolage were relied on
- The resulting non-profit ESCo has 3 heat networks, supplying 34MWhr of heat pa
- Carbon and cost savings are 45% in comparison with former electric heating.

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'If it hasn't been done in Aberdeen, it's not worth doing': Developing Urban Heat Networks in the UK.

1. Introduction

The UK Government Carbon Plan (2011) sets a target for radical reduction of greenhouse gas emissions from the entire building stock: 'by 2050, all buildings will need to have an emissions footprint close to zero' (p.5). Forty-five per cent of these emissions arise from use of fossil fuels for heating, but progress on decarbonisation of heat has been relatively neglected in policy:

'There has been a historic failure to get to grips with one enormous part of the energy jigsaw; the supply of low carbon heat' (Secretary of State, UK Government Department of Energy and Climate Change (DECC), 2013: 1).

One potential technical solution for urban areas, where demand is concentrated, is the use of heat networks or district heating (DH); current UK Government strategy (UK DECC, 2013) notes that:

'We should facilitate heat networks in denser urban areas where there is limited space for heat pumps. Storage on the networks will help with grid balancing' (p.78, Figure 7).

District heating is an established energy-saving technology in common use in other European cities, notably in Scandinavia, but also in Austria, Germany and Eastern European states. UK provision is however small scale and patchy, supplying only around 2% of heat demand (DECC 2013), and current heating is typically by individual building gas boilers, supplied by privatised gas transmission and distribution grids. Earlier UK policies to support DH development have had little impact (Russell, 2010), and there is limited research on the social and political processes entailed in formation of governance and organisation frameworks for retrofitting heat network infrastructure in cities. Most research has focused on technical and economic assessment of carbon saving, systemic efficiencies and cost reduction potential (see for example Connolly et al, 2014; EcoHeat4.eu, 2011; Greater London Authority, 2013; Kelly and Pollitt, 2010; Pöyry, 2009; Speirs et al, 2010).

In continental Europe, urban authorities have typically played a critical part in DH development, and UK policy also identifies urban authorities as significant intermediaries:

‘Local authorities are critical players in increasing the deployment of heat networks as they can create a supportive environment… and support or sponsor specific projects’ (UK DECC, 2013: 50).

Unlike in other European countries, however, such authorities have had no direct role in energy supply since the early 20th century when municipal supply was first regionalised and then nationalised. The regulatory framework for gas and electricity markets, which has evolved since privatisation in the 1990s, has prioritised short-term cost efficiencies, and secure returns on investment for transmission and distribution companies (Mitchell, 2008). At present a small number of large-scale, vertically-integrated corporations[1] control the majority of

[1] Known in the UK as the 'Big 6', these are British Gas Centrica, EDF Energy, E.ON, Scottish and Southern Energy, Npower and Scottish Power. They have a 98 per cent share of the household gas and electricity markets. Five are owned by transnational entities headquartered elsewhere.

generation and supply. Energy-related action by local authorities has centred on incremental efficiencies through building insulation, rather than area-wide investment; some urban authorities have ambitious sustainable energy plans, but these remain largely aspirational and subject to unresolved governance challenges (Bulkeley and Kern, 2006; Hawkey, 2012; Hodson and Marvin, 2009; 2010; 2012). A number of authorities have undertaken assessments of technical and economic feasibility of DH, but moving forward to business operation has proved complex, with 'feasible' projects stalling at the planning stage, decreasing in scale, and/or taking a long time to come to fruition (Wiltshire et al, 2013).

The purpose of this paper is to explore the social and political dimensions of project development, and hence to identify reasons why technically feasible projects may stall, and what can be done to overcome the difficulties. An in-depth case study of successful development in Aberdeen, north east Scotland, is used to analyse the process from origins to operation, and to identify the steps taken to resolve the difficulties of organisational coordination and governance. Establishing the technical and economic feasibility of proposed DH, with heat from local combined heat and power (CHP) generators, was an important, but, in may ways, more straightforward part of the process than addressing the social and political dimensions of business development and investment. Local political confidence in legitimacy of localised energy provision, and the mobilising of capacity, expertise and finance were particular areas of difficulty.

In Section 2, the paper outlines the environmental, technical and economic rationales for DH, before introducing the social and political dimensions of project development in the UK context. Section 3 describes methodology and data sources. Section 4 presents the results of the case study. Section 5 interprets and evaluates the governance and organisation solutions developed in Aberdeen in relation to the UK market and regulatory context. Section 6 concludes with suggested policy measures to address the organisational and governance issues, in order to secure the integrated social, economic and environmental benefits commonly attributed to DH.

2 Urban Heat Networks as Sustainable Energy Resource

2.1 Environmental, Technical and Economic Dimensions

Heat networks are a means of distributing heating and hot water, and also cooling, to multiple buildings and users via insulated underground pipes, and are a recognised means of reducing GHG emissions, while contributing to security and affordability (Connolly et al, 2014; Wald, 2013). Establishing such networks entails significant infrastructure investment, which is most cost-effective in urban centres, where demand is concentrated, and where different patterns of use mean that overall demand remains relatively high and stable. They are able to use currently wasted sources of locally-available heat, including recovered heat from industry, deep geothermal and sewage systems (Wald 2013). Even gas-fired CHP, a commonly used starting technology, is estimated to reduce carbon emissions by 40-50%, compared with UK current heating and cooling technologies; use of renewable or recovered heat confers additional reductions (UK DECC, 2013).

Technical and economic modelling of European Union heat demand and supply concludes that further development of DH, combined with improved building energy efficiency measures, would reduce the total cost of transition to low carbon energy by approximately 15% compared with the EU Energy Roadmap 2050 Energy Efficiency (EU-EE) scenario (Connolly et al, 2014). UK option appraisals draw similar conclusions: the UK Committee on Climate Change (2010) found that DH connected to low carbon electricity generation (fossil fuel with CCS/nuclear) was the most cost effective carbon abatement (-£110/tCO_2) measure; UK DECC (2009) estimated that biomass CHP connected to DH in suitable areas would provide annual carbon savings of 19.3 MtCO_2, in comparison with a saving of 2-3 MtCO_2 if the same buildings were heated with ground source heat pumps. By bringing the generation of heat and electricity closer to users, DH and CHP are estimated to reduce the £200bn+ investment required to upgrade electricity infrastructure. Heat supplied via networks means less electrification of heating, and therefore less grid reinforcement. Embedded electricity generation from CHP is also regarded as increasing the resilience of electricity supply, because it can operate flexibly as a form of energy storage and short-term operating reserve, thus reducing the need for investment in higher carbon stand-by plant and network infrastructure. This becomes more significant as increasing levels of intermittent wind energy are connected to the grid, and anticipated new load from electric vehicles and heat pumps increase peak demand (Spiers et al, 2010; Streckiene and Andersen, 2010).

Estimates of UK demand which could be met via heat networks vary from 14% to 43%, with UK DECC (2013) exploratory modelling concluding that up to 20% of domestic demand could be efficiently met by 2030.

2.2 Organisational and Governance Dimensions

Historically the establishment of such network technologies has been shown to require more than technical and economic evidence of attributed value. Eventual system configuration and performance of the 'hardware' is dependent not just on technical capacities, but also on the social and political structures which govern decision-making, as demonstrated by Hughes' (1982) comparative analysis of electricity network innovations in Berlin and London. Overall a 'seamless web' of social, organisational, economic and technical innovation, geared to new systems of provision, is encountered, with embedding of restructured relationships between suppliers and users, as well as the physical embedding of hardware (Hughes, 1982; Summerton, 1992). In the UK, periodic policy initiatives supportive of DH have not resulted in significant development. Structurally, energy efficiency has been a low priority in a sector governed by commercial economies of scale and what was a ready supply of North Sea gas; the resulting segmented supply chain has limited the scope for coordinated long-term planning associated with heat network infrastructure development (Hawkey, 2012; Russell, 1986; 1996; 2010). Current policy has again highlighted heat network potential for carbon and energy saving, but research investigating recent planned DH projects in the UK found that questions about political mobilisation, capacity, expertise and multi-party governance remained unanswered (Wiltshire et al, 2013).

Heat network infrastructure is susceptible to development at different scales, under multiple forms of ownership and management, with differential shares of social, environmental and financial returns. Technical expertise in UK energy systems and markets resides overwhelmingly with the large-scale utilities and their supply chains, but current regulation of privatised gas and electricity networks does not incentivise their investment in heat networks. Interest in investigating DH provision is hence more likely to come from end users than from established energy businesses, and may correspondingly serve a range of objectives associated not with energy technology *per se,* but with the potential of DH to serve local welfare and socio-economic purposes. These include urban regeneration and affordable warmth as well as carbon and energy saving (Hawkey, 2012). In the absence of substantial local capacity and expertise however, UK projects are generally small scale, and campus-based (universities and NHS bodies), or mediated by local authorities (Wiltshire et al, 2013). Private developers, or municipal property management businesses may opt for DH as a way of meeting low carbon building standards and area plans. Alternatively a local authority may develop DH in-house, act as intermediary in a separate business or community enterprise, engage in a joint venture with a private utility or operate a long-term concession contract for supply of heat and power, and possibly cooling, with a private provider.

The lack of direct capacity and expertise in localised energy provision, and the absence of codified technique, rules and contracts for heat network development in the UK, are likely to result in reliance on forms of social innovation and improvised learning in governance and business organisation. Improvised learning is compared by Karl Weick (1998) to the extemporisation displayed in jazz performances: the discipline of existing rules, routines and procedural controls are the foundation for innovative adaptation to constraints, producing embellishments on, and reinterpretations of, established practice. Such learning may move into bricolage, characterised by practically (as opposed to formally) rational activity, based on the creation of a latticework organisational structure emergent from sequences of indeterminate events (Levi-Strauss, 1966). Bricolage entails reasoning situated within concrete circumstances, and a logic derived from a web of interconnecting events (Engelen et al, 2010; Turkle and Papert, 1992). Bricolage is treated by Levi-Strauss as a contrasting means of knowledge formation to that of formal scientific rationality, which commences from theoretical axioms intended to predict and control events. To those trained in Anglo-American analytic reason, bricolage may appear limited, but in a comparison of technological innovation in the wind energy sector, the Danish bricolage model was found to be more effective, at least in early stages of development, than the formalised rationality of a top-down 'break through model' pursued in the USA (Garud and Karnøe, 2003; Hendry and Harborne, 2011). Such processes typically rely on a 'community of practice' (Wenger, 1998) where interested parties interact in mutually-acknowledged joint enterprise, to develop knowledge through applied reason, use and interaction (Amin and Roberts, 2008). The development of localised heat provision, under current UK market structures, seems likely to require such a community of practice to create connections between local knowledge, political processes and interests, and formal financial, legal and technical expertise in energy systems, and hence to produce material change in provision. In the following sections of the paper, such processes are discussed in relation to a case study of Aberdeen DH and CHP development.

3. Methodology

Case study data is derived from semi-structured interviews with participants in project planning and development, and analysis of Aberdeen Council, Aberdeen Heat and Power Ltd (AHP) and related documents. Interviews were conducted with the lead council officer, two AHP Board members, one district energy consultant who was also the second Chair of the Board of AHP, the AHP general manager, three representatives of the accountancy firm involved in establishing the financial model, and one representative of the legal firm advising on business structure, governance framework and contracts. These varied in length from one to four hours and were audio-recorded and either partially or fully transcribed. Updating on continuing plans and developments has occurred through district energy network events, industry conferences, meetings where AHP representatives have advised other community groups on business development, and lastly joint researcher- and practitioner-led knowledge exchange workshops with UK local authorities. Observation and participant observation by the author in Scottish and UK government energy and climate change meetings have provided contextual data on district energy policy processes.

4. Case Study Results: Developing Low Carbon, Affordable Energy in Aberdeen

Although most UK local authorities have made public commitments to climate change mitigation, capacity for material engagement in energy provision is limited. Initiatives such as DH may emerge from a range of service functions, with different substantive goals. District heating and CHP systems in Aberdeen emerged as potential solutions to the problems of improving the city's 1970s council-owned social housing, occupied by low income households: fifteen per cent of Aberdeen households live in relative poverty, and the poorest are concentrated in multi-storey housing. In 2002, the city council established a non-profit energy services company, Aberdeen Heat and Power Ltd (AHP), with the primary purpose of working for the benefit of the citizens of Aberdeen. At present, AHP owns and operates three gas-fired CHP energy centres, supplying cost-based heating and hot water to around 1500 flats in 24 of the city's 59 multi-storey housing blocks, as well as a school and an increasing number of public facilities. Some of the co-generated electricity is supplied via private wire to the school; the remainder is sold into the public network, with revenues used to maintain a low heat tariff, as well as generating a contingency fund for further investment. Its governance and organisation structure is summarised in Figure 1 (insert here).

Technical systems developed under the fifty-year framework agreement between AHP and the council[2] are summarised in Figure 2 (insert here).

During 2012-13, the network was extended into the city centre, with further connections to NHS facilities and the city's Town House. Total network length is currently 14K, and annual heat supply 34MWhr. Very significant carbon savings and heat cost reductions have been achieved. Carbon saving is estimated to be 45%, in comparison with former electric heating systems in multi-storey blocks

[2] This is governed by a *Teckal* exemption which provides that, in certain circumstances, the award of a contract by one public body to another separate legal person will not fall within the definition of 'public contract', with the result that EU law will not require the contract to be put out to tender. The exemption comprises both a 'control test' and a 'function test'. (1) The local authority must exercise similar control over the contractor to that which it exercises over its own departments, and (2) the contractor must carry out the essential part of its activities with the controlling local authority or authorities.

and replacements for central heating boilers in public buildings. Heat tariffs for tenants are very affordable (currently £10.54 per week, a saving of approximately fifty per cent on equivalent electric heating). The National Home Energy Efficiency Rating (NHER) of the housing blocks with improved insulation and connected to the heat network was reported by council as improved from 3.3/10 in 1999 to 7.19/10 in 2009.

4.1 Origins of the DH & CHP Initiative: Multi-Level Governance and Fuel Poverty Politics in the UK

Campaigns centring on the eradication of 'fuel poverty' in the UK date back to at least the 1970s, with a formal policy goal gaining cross-party support in the 1990s (Koh et al, 2012). As in Aberdeen, such campaigns have had a strong local dimension, including commitment among community organisations, local authorities and charities to locally achievable demonstration projects. At UK level, the campaign was advanced by the environmentally-oriented Association for the Conservation of Energy (ACE), who pursued legislation as a means to integrate social with environmental goals. In UK Parliament, Diana Maddock, Liberal Democrat MP for Christchurch, a constituency with a high percentage of pensioners, advanced the campaign for a Home Energy Conservation Act (HECA) in the face of a Conservative government plan to introduce VAT on fuel at 17.5%. The Act was introduced in 1995 by the Conservative government, and climate change was factored into the debate, resulting in a requirement on local authorities to identify cost effective and practical measures for a target reduction of 30% in home energy consumption and CO_2 emissions between 1997 and 2007.

Although HECA-related action was uneven, in councils such as Aberdeen[3] the legislation cohered with established cross-party political commitment to reduce fuel poverty. Local political consensus, and commitment by the Council Chief Executive and Director of Housing created legitimacy for direct allocation of resources to address HECA targets, and a Home Energy Co-ordinator and Administrative Assistant were appointed. The Coordinator, with expertise in community development, rather than a technical background in local government and housing services, initiated an open-ended appraisal of options, oriented to an Affordable Warmth Strategy adopted in 1999. The strategy centred on use of the housing capital budget to reduce the use of energy by 30% in the least thermally efficient high-rise flats, where it was estimated that 70% of households lived in fuel poverty.

4.2 Articulating Affordable Warmth: a 'Boundary Object' to Mobilise Support for CHP and DH Development

'Affordable warmth' does not translate directly into a specific programme of work; in this case, its ambiguity enabled its use as a boundary object (Bowker and Starr, 2000), which serves as a weakly structured means of facilitating negotiation, and building cooperation, across specialist interests, without having to achieve precise consensus on ends and means. Boundary objects rely on intermediaries able to interpret the potential for differing interests to be served. The Home Energy Co-ordinator played this role, characterising her work as identifying the goals of different council service groups and inter-agency

[3] A key organisation, SCARF (Save Cash and Reduce Fuel), was set up in the 1980s as a registered charity with financial support from the council under the Urban Aid programme and was one of a number of inter-connected anti-poverty projects.

planning bodies, and interpreting affordable warmth and its significance accordingly. Different strands of work elaborated the core concept of affordable warmth, including housing condition surveys, assessment of National Home Energy Efficiency Ratings (NHER) of council stock, thermal imaging of the city as a means to generating consensus over priority areas of investment, and regular progress updates geared to mobilising political support.

This intermediary activity, backed by the Chief Executive, Director and Assistant Director of Housing, and an environment officer committed to action on climate change, led to mobilisation through a council conference on climate change mitigation in 2002, and the improvised drafting of an energy policy 'in the pub' afterwards. The visibility of ecological and social issues increased, renewing political commitment in a further articulation of strategy: 'The environmental aim of reducing CO2 emissions, and the social aim of eliminating fuel poverty, have consistently been viewed as two sides of the same coin by Aberdeen City Council' (*Fuel Poverty Strategy* 2002 p.3). The council proceeded to develop further knowledge through a Carbon Trust 'Pathfinder' programme with subsequent adoption of a Carbon Management Plan.

Action coalesced around planned regeneration of electrically-heated multi-storey housing, bridging and integrating differing internal purposes: tackling fuel poverty, environmental protection, and improved economic returns to council from housing stock. A technical-economic options appraisal was commissioned to identify means for:

- A substantial improvement in the National Home Energy Rating (NHER) of the city's multi-storey flats;

- Affordable warmth for tenants;
- Reduction of carbon emissions.

Recommendations also had to be affordable to council and the resulting report showed the short-term lowest cost solution as refurbished electric heating. It also included evaluation of the potential to provide a common source of heating to clusters of neighbouring buildings via a heat network, but this had a relatively high capital cost. Political mobilisation around the principles of affordable warmth and carbon reduction nevertheless enabled challenge to the short-term cost calculus, and defence of an end user perspective, based on whole life cost analysis including the high cost in use of electric heating to tenants, and its high carbon. The lowest 'cost in use' recommendation was external insulation of multi storey bocks and installation of CHP with DH, but the high capital cost of the external cladding, relative to the small additional saving for tenants, resulted in a compromise preference for CHP and DH without cladding[4].

4.3 An Emerging Community of Practice

The unfamiliarity of CHP and DH technologies in the UK, and lack of local energy capacity, knowledge and expertise, meant that their technical and economic feasibility did not equate to acceptance of efficacy. The recommendation was highly contested, despite broadly-based political support for addressing fuel poverty, with some local politicians, housing, finance and legal officers defending lower cost business as usual and the high risks of alternatives. Tenants with fuel debts, and accustomed to self-disconnection using a pre-payment meter to

[4] In practice many of the tower bocks were over-clad as part of regeneration, with part or full cost covered by successive variants of the energy efficiency obligation placed by government on energy suppliers.

control spending, were also sceptical, but cautiously interested in a fixed heating charge paid with rent to enable budgeting. This option entailed risk to council finances, incurring objection from finance officers. Beset by contest over the formal evidence of technical and economic feasibility, the Home Energy Coordinator described the stance on occasion as part of the local ethos: 'If it hasn't been done in Aberdeen, it's not worth doing'. She sought to construe the multiple set backs as 'hurdles' rather than 'barriers', a distinction helpful to her in improvising means to get round or over difficulties. Intensive research and intermediary activity to address the multiple questions posed by tenants, politicians and officers, convinced the Coordinator that 'it would work', to the extent that she was willing to make promises to politicians and householders about price and performance.

The emerging 'latticework' project organisation created bridges between politicians and officers from Housing, Environment and Infrastructure, Planning and Resources, Highways and Finance, and was critical to improvised action at the margins of multiple statutory service domains. The Aberdeen local project network drew on the HECA officer network to create links to energy systems' technical, legal and financial expertise. The consulting engineer appointed to develop system specifications and costings also provided 'moral support' (Home Energy Coordinator) and practical reasoning in the form of 'many hours walking the streets' (Coordinator) to establish confidence in the feasibility of proposed infrastructure routes and configurations. The anti-poverty focus of Aberdeen coalition politics, combined with Scottish government commitment to poverty reduction, enabled social objectives to be maintained. Negotiation centring on the ‘affordable warmth’ objective resulted in recommendations to create a stand-alone non-profit business, with local control over system design and development, and asset ownership. A low investment rate of return on finance was acceptable, given the primary return sought was in well-being and local economic benefit. The loosely configured, geographically diffuse project latticework was hence critical to formation of knowledge about, and shared belief in, the integral social, economic and environmental value of localised energy, and the feasibility of governance through a non-profit enterprise. The flexibility of the proposed CHP and DH solution as a hinge connecting multiple local interests was however critical: as a formula for addressing fuel poverty, it had to be made congruent with improved financial returns from housing stock and carbon reduction; tenant support was contingent on a fixed price for heat, and the expected energy cost reduction to council persuaded finance to support the strategy, and in principle to accept the risk of tenant non-payment under the tenant-preferred heat with rent formula.

The benefit to users of DH and cost-based tariffs however meant higher capital costs to council, resulted in dispute about affordability and necessitating financial ‘bricolage’ to assemble components of funding ‘without revealing to anyone what amounts other bodies were giving’ (Coordinator). In this instance, a change of UK government from Conservative to Labour in 1997 proved highly significant in the eventual formation of Aberdeen Heat and Power Ltd. The election resulted in greater devolution of power to Scotland, Wales and Northern Ireland, and increased the momentum of climate change politics, including short-term (2002-2007) financial commitment of £50M from UK Treasury Capital

Modernisation Funds for a Community Energy Programme (CEP) to support DH developments led by public bodies.

The Community Energy Programme again made cross-sector expertise available to public sector teams to advise on governance and organisation structures, energy markets and business and financial planning. In addition to grants for half of the costs of technical feasibility assessment, the Programme provided up to 40% of eligible capital costs. The CHP/DH feasibility study for Aberdeen council had provided costings for a sample project for one cluster of multi storey housing blocks, enabling an application under the 2002 'pathfinder' round of CEP funding for development of a pilot scheme in the Stockethill area of the city. Aberdeen subsequently became the lead UK recipient of funding under the CEP, receiving two further capital contributions for systems in Hazlehead and Seaton. Part of the explanation for this success is attributable to structures of UK multi-level government, and the decision by the then Labour-Liberal Democrat coalition government in Scotland to fund a cross-sector community energy network to facilitate funding applications. Out of a total of 57 projects eventually receiving capital funding, 23 (40%) were in Scotland, demonstrating the impact of practice-based regional coordination on shared learning and knowledge formation.

The final decision to proceed required full agreement of council, supported by Environment and Infrastructure, Housing, and Planning and Resources Committees, posing considerable mediation and coordination demands in relation to contested claims of value, risk and affordability. Council legal advice ultimately opposed the proposal on the grounds that financial risk remained with the council. The deputy council leader, a Labour councillor and incomer, chaired the key committee: ‘At the founding meeting he said “we are obliged to seek the advice of the council’s solicitor, but we are not obliged to take it. Therefore it is noted.” So he put it to one side. So he had the political courage’ (member of AHP Board and district energy practitioner). The committee decision to proceed led to establishment of AHP Ltd, and the opportunity for a first CHP/DH development.

4.4 The Practice-Based Economics of DH and CHP in Aberdeen

The selection of the first Aberdeen scheme was not governed by technical and economic feasibility criteria alone (these criteria in fact suggested a different priority location), but instead incorporated local practice-based knowledge about non-monetarised costs associated with organisational decision-making structures, and political and social processes. Four housing blocks in the Stockethill area were selected on the basis of good fabric condition, anticipated ease of implementation, and other ‘non-technical information known to the housing investment staff’ (Stockethill Evaluation Report). The latter included the likelihood of positive evaluation by householders, who were an older, stable population expected to understand the benefits of the scheme and to be effective ambassadors. The project was relatively simple not just technically, but in relation to council finance structures and decisions, requiring capital contributions only from housing services. In subsequent developments, more typical of the diverse heat load connections needed to optimise CHP and DH efficiencies, funding had to come from multiple budgets held by different council divisions, with the attendant complexities associated with consent and legal contracts. The Stockethill scheme was effectively part of a pragmatic strategy to build shared learning, and political and social capital, as a foundation for anticipated future developments and a route to standardising project management.

In the context of limited capacity and expertise, the scheme proved to be highly demanding for the project team, with the evaluation report noting the intensive officer workload and high stress. A loan also had to be raised to finance the high risk construction phase, to be undertaken by a company with no track record and no existing assets. The council finance team were persuaded to act as loan guarantor, which reduced the rate of interest on the ten year loan to AHP from the Cooperative Bank. The debt was repaid from the Council's housing capital programme as funding became available, from the CEP capital grant payable on completion and from operating revenues. The council's internal evaluation showed that the system was delivered on budget, and met affordable heating and carbon saving goals. Subsequent capital investment has been managed via direct council borrowing from Public Works Loan Board, with capital contributions from the UK CEP, and from successive energy company energy efficiency obligations.

The first phase of the third, and most ambitious, project in the Seaton area of the city proved most contentious, but also provided the key to subsequent expansion and assemblage of additional finance. This third application for CEP funding was based on contracted carbon saving from DH connection of 11 multi-storey housing blocks via a further CHP energy centre. Poor fabric condition of a number of blocks resulted in their unplanned withdrawal, risking loss of grant.

Aberdeen council beach leisure complex was selected as an alternative, but at additional cost. The AHP volunteer board of directors perceived themselves as uninformed about the changed plan and financial risk. Crisis and dissent followed, with resignations threatened. As an assurance, AHP had been established under the requirement that financial accounting would be managed directly by the council. The crisis however resulted in concern among board members about the adequacy of the arrangement, and a resolution to seek independent financial advice. This resulted in arrangement of an overdraft facility, also underwritten by Council, to resolve the short-term cash flow crisis, and coincidentally provided the impetus for greater strategic responsibility for business development to be taken by the AHP Board.

Further accretion of practice-based knowledge has included increasing strategic orientation to wholesale market contracts for purchase of gas supply for CHP engines and back up boilers, and development of competence in multi-party legal contracts and agreements. Bricolage has continued to be critical to assembling finance for scheme expansion after the CEP programme ended in 2007. Under successive variants of the UK energy efficiency obligation on utilities, for example, measured carbon savings from proposed CHP energy centre and DH extensions were structured as a tradable currency and offered to the highest bidders in what was typically a drawn out and uncertain process. When ad hoc Scottish government funding became available in 2012, the earlier crisis relating to oversizing of pipework in the third project allowed for network extension to the city centre, in turn resulting in establishment of District Energy Aberdeen Ltd (DEAL) as a commercial subsidiary of AHP, and opening up further business opportunities. The home energy coordinator, who subsequently moved into a cross-council strategic role in energy management commented:

'There's always money around somewhere that you can screw in to make a project work. You just have to go after it'.

5 *Explaining Aberdeen DH and CHP Development*

Although shaped by the increasing prominence of climate politics, the Aberdeen development of DH and CHP is not explicable as the outcome of a formally rational technical and economic assessment of least cost pathways for UK low carbon energy transition. Instead the localised provision of DH, on a non-profit basis, was identified by the council as a new means to a long-established political aspiration to reduce poverty among the city's poorest households. It was an opportunity configured from a locally-constituted readiness to exploit the political dynamics of UK multi-level government while improvising in development of a practice-based economics of energy use. In this case, Conservative UK government legislation on home energy conservation led to the critical appointment of a local project leader; a subsequent UK Labour government linked climate change mitigation objectives with energy and rising household bills, resulting in availability of finance under the Community Energy Programme, and Scottish government poverty reduction and community energy strategies provided regional coordination for an emerging community of practice. Housing regeneration was a wider regulatory lever used by Scottish and UK governments, which aligned with Council interests in improving economic returns from housing stock.

In the UK energy market and regulatory context, DH and CHP are situated as economically marginal propositions; crucially there is no heat market equivalent to the gas market regulatory framework to provide a secure return on investment from energy users or to underwrite loans. Aberdeen developments were instead the *non*-market product of anti-poverty campaigns, evolving political dynamics of multi-level governance, climate protection measures and the ensuing interactions of practical idealists. The social priority placed on welfare via affordable warmth justified the creation of a non-profit business, limited by guarantee, with governance by a volunteer board of councillors and community representatives, and financial risk underwritten by Aberdeen council. This structure resulted in the ability to use a cost- rather than market-based heat tariff, and to enable the Council to meet affordable warmth targets more rapidly than under internal governance arrangements (EST, 2003). The arms length business structure benefits the council by ring-fencing finances and management responsibility, and facilitating capital investment in housing stock refurbishment, while spreading the capital cost over several years (EST, 2003). A stand-alone organisation structure has the further advantage of potential for subsequent use of third-party capital for expansion. Local authorities are also able to set a lower rate of return on investment (typically around 6% in comparison with 12%+ in private sector) for business planning. This enables more projects to proceed, and local control over revenues and future business direction to be retained. The municipal model however means that financial risk is retained by the council, with loans secured against council revenues. Project management needs to be built on robust assessments of heat cost reduction and, in the case of CHP, revenues from electricity, as well as securing long term diverse heat load, and mitigation of risks stemming from construction, fuel purchase, and operation.

Aberdeen projects were delivered on budget and the original bank loan repaid. Governance via a stand-alone company is regarded by the auditors as integral: 'it has never been the mind set that the council is behind this and will pick it up' (council financial auditor). At the same time, AHP has generated political capital for the council, through material impact on fuel poverty and carbon saving. Other forms of value have also been realised, not least in relation to community welfare and council revenues from improvements to the housing stock, some of which was hard to let and deteriorating due to damp. Occupancy rates have increased, turnover has declined, health has reportedly improved, and building fabric maintenance is reduced. This has in turn improved the local economics of CHP and DH: 'Now word has got round [in the Seaton area], take up of the new offer is 80%, while the original project had around 40% take up' (local accountant).

Contracts are in place for connection of a further 11 tower blocks to be completed by 2015; the connection of additional heat sources is being considered, and the company is positioned to move into commercial heat supply. In 2013 AHP received a global district energy award from the combined boards of the International Energy Agency, International District Energy Association and Euroheat and Power. Its trajectory suggests that a small scale, largely improvised social innovation, which commenced with a £1.8M pilot scheme connecting four 1970s tower blocks to a gas-fired CHP engine may yet deliver a city centre non-profit, locally owned and operated heat network. 'Clarity of vision' (council financial auditor), combined with determination of the lead officer, were significant: a city 'heat main' has long been the imagined long term goal, characterised by those involved as the 'ring of fire' and drawn as a red line on city maps in the AHP office.

6 Conclusion

Demonstration projects such as that in Aberdeen have contributed to an embryonic heat networks community of practice which provides a counterpoint to the current orthodoxy of UK energy markets and regulation. Could such small-scale projects become scalable models for low carbon, secure, affordable heating provision? The trajectory of development, in conditions of political and economic uncertainty over energy policy, is unclear. Market regulation and taxation powers largely remain with the UK government, which limits authority and capacity at devolved and regional levels, and end-use energy efficiency remains secondary to incentives for further exploitation of fossil fuel energy.

If the attributed sustainability benefits of urban heat networks are to be realised in practice, then central government action is needed to resolve the organisational coordination and governance challenges faced by project teams such as those in Aberdeen. In current UK political-economic circumstances, policy redirection seems likely to be dependent on a social systemic user-, rather than technology-led, model of innovation, underpinned by a regional economics of energy and carbon saving. Relationships between UK central and local governments are however marked by a history of low trust, with bureaucratic and fiscal reforms progressively centralising budgetary control over local spending, and extending market mechanisms and competitive contracting (Le Gales, 2002; Le Gales and Scott, 2010). Local powers of comprehensive territorial planning, and capacity to realise locally-defined goals are correspondingly circumscribed. The absence of significant statutory powers over energy services means that most authorities lack capacity and expertise, and hence lack governance structures for heat network infrastructure planning.

The Aberdeen project team gained a precarious hold on energy expertise and finance, with high personal costs for those involved. Project evaluation reports note the multiple uncertainties and unplanned events which arose during system construction, from internal council decision-making and planning permission issues to coordination and communication with householders, building users and other building services' specialists. The demands of long working hours, few resources and burdens of responsibility without clear authority can however be reduced by consistent political, policy and regulatory support for transition to a resilient low carbon energy system. This would enable a cross-sector community of practice for urban heat network provision to develop capacity to interact in formulation of policy and funding pathways. Like many cities Aberdeen has a culture of 'civic pride' in independent-minded adaptation to circumstances (Fraser and Lee, 2000). There is therefore potential for urban 'coalitions of the willing' to emerge as catalysts. Such coalitions come about, as in Aberdeen, through the political alliances necessary to holding power, and include local activists as well as city officials charged with the multiple obligations of reducing carbon, cutting costs, regenerating the local economy and addressing the local consequences of welfare restructuring. They include the devolved governments, who look for political capital gained from alignment with promising innovations which contribute to strategic goals.

Heat policy may itself work as a 'boundary object' in supporting development of such a UK community of practice. The relative neglect of end use of energy for heat in energy policy has created scope for improvised policy learning for a user-oriented economics of heat provision and for divergence in energy governance across the UK: heat policy has perhaps been devolved 'by omission rather than by decision' (UK DECC officer). Urban heat network projects such as those in Aberdeen and other UK cities can be interpreted as evidence of a reassessment of energy governance, which is feeding through into policy. At a UK Workshop organised by the researchers in 2013, the DECC officer's presentation stated 'we want the heat policy paper… to explain why decentralised solutions will be important'. UK DECC has funded district energy pilot projects in English 'pioneer cities' and set up a Heat Networks Delivery Unit under its 2013 strategy. The Unit has a small budget of £6M over two years to support English and Welsh local authority procurement of technical reports and advice on commercial viability. Building on the earlier community energy network, Scottish government has created the framework for a coordinated approach under its Heat Network Partnership and Heat Generation Policy and loan funds: 'Governments can always find money; if there's a will there's a way' (Scottish Ministerial comment during his speech at a DH Leadership event). Routes to reducing development risk and cost of capital remain uncertain however, and these initiatives alone are unlikely to resolve the coordination and governance questions exemplified in Aberdeen. UK and Scottish government strategies acknowledge the need for longer-term institutional changes, but how the systemic change needed to create long term consistent support for DH and CHP might be brought about is unclear under a commitment to current market principles:

‘Across all the different heating strands, the Government wants to make progress without prescribing use of specific technologies. Instead, information for market players, including households and businesses, should be improved to enable effective decision-making’ (UK DECC 2013: 79).

In the absence of any existing market for heat, and affordable long term capital for heat network infrastructure, technical and economic feasibility alone are insufficient to stimulate investment in urban DH systems. The UK energy market context creates systemic risks for DH and CHP investment, indicating the need for a more favourable, less uncertain, policy framework to bridge the gap between policy statements and practice, and to reward significant urban leadership in energy governance. Precise policy measures need to be coordinated between local and central governments, but some basic principles can be derived from the Aberdeen case study. Benefits of local authority momentum could be secured by provision of affordable long term finance or financial guarantees for non-profit or joint public-private ventures. This could come from UK infrastructure funds, differently structured GIB finance suited to municipal enterprises, or European sources such as regional development funds. More devolution of powers and finance to city regions would contribute to capacity for economic regeneration, and could be structured by specific requirements relating to low carbon urban heat network infrastructure, where this is effective under a whole life cost model incorporating social and environmental benefits.

Where CHP is used as a heat source, the electricity exported could be granted the same status as large scale nuclear or offshore wind, under the new 'contracts for difference' strike prices for low carbon electricity supply. This would reflect the efficiency gains from generation of electricity close to its point of use. Operators would then have a risk underwriting mechanism. This is however a form of regressive taxation, because it operates as a levy on energy bills. The same is true of current energy company obligations (ECO) to provide finance for carbon and energy saving projects; ECO, and its predecessors, have contributed to locally-led heat network retrofit projects, but have been complex and subject to inconsistent carbon pricing. Recent reductions in the scale of funding have also stalled projects. Such levies could be funded fairly, and their resources deployed more speedily and consistently, through general taxation.

For heat network investment to be cost effective, the transaction costs currently incurred in multi-party coordination of building owners, heat suppliers, planners and system operators need to be resolved. This requires more directed use of planning powers and heat mapping to prioritise areas for network development and anchor load connection, as in other European countries such as Norway or Denmark. Much heat mapping work has been completed in the UK, but strategic use has been limited. Having identified areas of high density demand, and network feasibility, large building owners would need to be under an obligation to connect to local heat (and cooling) networks, and producers of waste heat would need to be obliged to identify means to supply the network, in line with EU Energy Efficiency Directive requirements. Such obligations assist in maximising cost effectiveness and carbon and energy savings, and in turn provide secure revenues for operators. With stronger government mandates, public buildings and multi-storey housing could be required to connect to heat and cooling networks on a timetable aligned with renovation and heating replacement schedules. Commercial building users required to register for the UK energy efficiency tax, the CRC, already have a financial incentive to connect, because heat supplied via heat networks is rated as zero carbon. A general energy efficiency tax could be used to incentivise all commercial building owners to connect. Such revenue support measures need to be balanced with a system for licencing and regulation to prevent abuse of long-term monopoly supply contracts. The Danish Energy Regulatory Authority (DERA) for example regulates electricity, natural gas and district heating markets. For district heating, both production and network companies are regulated as non-profit undertakings. DERA monitors prices and delivery terms, and takes action if these are not in line with the non-profit model or if they are in any other way unfair.

Whatever their exact form, any policy changes are likely to be more effective in shaping a sustainable energy system if they capitalise on the momentum for practice-based knowledge, and the applied economics of energy use at urban scale. From an end use perspective, energy technologies such as heat networks are not an end in themselves, but a potential means to multiple socio-economic and environmental benefits. For the user perspective to be served, transparent appraisal of the full range of technology options and governance models is critical. On this basis, urban governance of low carbon heat and power *is* now being done in Aberdeen, so it must be worth doing.

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Figure(s)

Figure 1 - Governance And Organisation Of Urban Energy In Aberdeen

Council lead objective	Affordable warmth for social housing
Organisation structure	Company limited by guarantee and by membership, under local ownership and control, with asset lock
Business model	Non-profit ESCo; any surplus reinvested or used to lower cost of heat to housing tenants
Governance structure	Volunteer board of directors including councillors, community and business organisations and former council officers
Heat tariffs	Cost-based
Main customers	Public housing tenants
Other customers	Community sport, leisure and education facilities
Finance	UK and Scottish government grants, city housing capital, prudential borrowing, bank loan and overdraft
Risk mitigation	Loans guaranteed by city council; council long term contract for purchase of energy

Figure 2: District Heating and Combined Heat and Power Developments, Aberdeen Council and Aberdeen Heat and Power Ltd

Energy Centres and Networks	CHP capacity	Capital Funding	Total Infrastructure Cost
Stockethill	210 kWe 300 kWth	53% Housing capital 40% UK CEP grant 7% Energy utility EEC	£1.8M
Hazlehead	300 kWe 488 kWth	53% Housing capital 40% UK CEP grant 7% Energy utility EEC	£1.6M
Seaton	2100 kWe 3000 kWth	Phase 1 60% Housing capital 40% UK CEP grant Phase 2 60% Housing capital 40% Energy utility CESP	£3.3M
City centre network extension		Scottish Government grant	£1M

Note: The energy utility Energy Efficiency Commitment (EEC) was the energy company obligation in place in 2002; subsequently replaced by the Community Energy Savings Programme (CESP) and currently the energy company obligation (ECO).

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